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# Application of chemical oxidation for pharmaceuticals removal in wastewater effluents

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## Executive Summary

This study was conducted to evaluate the potential of the chemical oxidation processes chlorine dioxide ( $\text{ClO}_2$ ) and ozone ( $\text{O}_3$ ) as tertiary treatment step to remove trace active pharmaceutical ingredients (APIs) in Swedish municipal wastewater treatment plants (WWTPs). Wastewater effluents of varying organic load (COD  $\sim$  30-90 mg/L) were collected from different WWTPs in Sweden to represent different types of biological treatment. Batch experiments were carried out employing  $\text{ClO}_2$  (0-20 mg/L) and  $\text{O}_3$  (0-12 mg/L) to treat biologically treated wastewater spiked with approx. 1  $\mu\text{g/L}$  mixed APIs. Additionally, treatment with peroxone ( $\text{O}_3/\text{H}_2\text{O}_2$ ) is carried out to enhance API oxidation rate by non-selective hydroxyl radicals. Some of the APIs investigated are shown in Fig. 1 and 2. From the  $\text{ClO}_2$  treatment, API removal varied from no significant removal at the highest  $\text{ClO}_2$  dose to more than 90% removal with 0.5 mg/L of the oxidant. The low COD effluent exhibited most of the APIs removed at 5 mg/L  $\text{ClO}_2$  dose while a significant increase in API removal from the high COD effluent after treatment with 8 mg/L  $\text{ClO}_2$ .

Shown in Fig. 1, treatment with  $\text{ClO}_2$  of low COD effluent removes diclofenac by >90% at low oxidant dose of 1.25 mg/L while in high COD effluent around 3 mg/L  $\text{ClO}_2$  is needed to reach 90% removal. Repaglinide is also removed at low  $\text{ClO}_2$  dose. In comparison to ozonation, the same degree of removal of these APIs is reached but with much higher ozone dose. On the other hand, citalopram and trimetoprim in low COD effluent (Fig. 2) can be removed by ozonation at lower dose than  $\text{ClO}_2$ . Ozonation significantly enhanced the removal of most APIs including carbamazepine, metoprolol, flutamid, bupropion and beclomethasone (Fig. 2). In addition, ozonation allows removal of ibuprofen in low COD wastewater but at higher oxidant dose.

This study illustrates that treatment of wastewater containing trace pharmaceuticals is possible with either chlorine dioxide or ozone as additional treatment step depending on the target pollutant and taking into consideration the economic aspect of the process. For small-scale WWTPs,  $\text{ClO}_2$  treatment could be an option when ozonation is too expensive and complicated to operate.

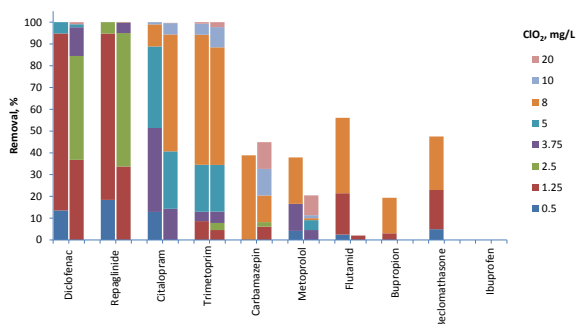


Fig. 1. Comparison of API removal by  $\text{ClO}_2$  in low (left bar graph) and high COD (right bar graph) effluents.

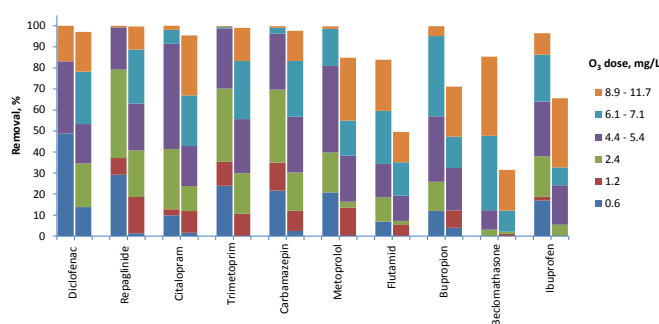


Fig. 2. Comparison of API removal by  $\text{O}_3$  in low (left bar graph) and high COD (right bar graph) effluents.